

NASA AND ESA PARTNERSHIP ON THE MULTI-PURPOSE CREW VEHICLE SERVICE MODULE

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In March 2011, NASA and ESA made a decision to partially offset the European obligations deriving from the extension of the ISS Program until the end of 2020 with different means than ATVs, following the ATV-5 mission foreseen in mid-2014. NASA and ESA considered a number of barter options, and concluded that the provision by ESA of the Service Module and Spacecraft Adaptor for the NASA Multi-Purpose Crew Vehicle (MPCV) was the barter element with the most interest. A joint ESA - NASA working group was established to assess the feasibility of Europe developing this Module based on ATV heritage. The working group was supported by European and US industry namely Astrium, TAS-I and Lockheed-Martin.

This paper gives an overview of the results of the on-going study as well as its projected utilization for the global space exploration endeavour.

I. INTRODUCTION

The Multi-Purpose Crew Vehicle, (MPCV) is the spacecraft that NASA intends to use to send humans and cargo into space beyond low earth orbit and to return them safely to earth. The first two exploration missions consider an uncrewed beyond Earth orbit (lunar flyby) mission for system qualification at the end of 2017 as well as crewed beyond Earth orbit mission to higher lunar orbit no later than the end of 2021.

The MPCV configuration consists of:

- Crew Module (CM)
- Service Module (SM)
- Crew Module Adaptor (CMA)
- Spacecraft Adaptor (SA)
- Spacecraft Adaptor Jettisoned Fairings (SAJ)
- Launch Abort System (LAS)

An ESA provided Service Module would make use of knowledge and hardware development experience from the Automated Transfer Vehicle (ATV) and other European heritage systems. The SM provides thrust after upper stage/launch vehicle separation; generates electrical power; regulates heat for the life support and avionics equipment; provides a platform for unpressurized cargo; and stores potable water, oxygen, and nitrogen. For selected subsystems NASA provided hardware is

under consideration to avoid parallel development and limit cost / risk. To enable versatility in multiple mission configurations the SM will have a modular configuration and will be compatible with the Ariane 5 launch vehicle. Following successful completion of the initial feasibility working group in September 2011, on 4 October 2011, NASA Associate Administrator for Human Exploration and Operations and ESA Director General signed a "Framework between NASA and ESA Concerning Follow-on Activities required for decisions to be taken in 2012 for the 2016 through 2020 ISS Common Operation Costs (CSOC) Barter". Both Agencies agreed to extend the assessment phase of the potential MPCV cooperation in order to achieve technical and programmatic maturity necessary for the decision to be taken to the ESA Council at Ministerial level to be held in November 2012. Should ESA and NASA decide to pursue the collaboration past Phase A/B-1, a dedicated implementing arrangement, pursuant to the *Agreement among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation, and the Government of the United States of America Concerning Cooperation on the Civil International Space Station*[1] (hereinafter the "IGA"), and the *Memorandum of Understanding between*

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the National Aeronautics and Space Administration of the United States of America (NASA) and the European Space Agency (ESA) Concerning Cooperation on the Civil International Space Station[2] (hereinafter the “MOU”), both signed on 29 January 1998, and collectively referred to as “the Space Station Agreements.” If the Ministerial Council decision in November 2012 is in support of this effort, the Implementing Arrangement would be established after approval by the United States Government through the C175 process and, as necessary, other mechanisms in the December 2012 timeframe.

In November 2011, ESA and NASA initiated MPCV-SM phase A / B1 activities. This phase includes conducting a System Requirements Review (SRR) and System Definition Review (SDR) in 2012. The results of these efforts are described in the following paragraphs.[3]

II. MPCV CONCEPT AND MISSIONS

The Multi-Purpose Crew Vehicle (MPCV) is a spacecraft that is being built by Lockheed Martin for NASA, the national space agency of the United States, based on designs and tests already completed for the Orion spacecraft. The MPCV was announced by NASA on May 24, 2011.



Figure 1: MPCV Crew Module

The Multi-Purpose Crew Vehicle (MPCV) is a pressurized, crewed element that transports up to four crew members from the Earth's surface to a nearby destination or staging point and brings the crew members safely back to the Earth's surface at the end of a mission. The MPCV provides all services necessary to support the crew members while on-board for shorter duration missions or until they are transferred to another element.

The MPCV consists of a crew module (CM), a crew module adapter (CMA), service module (SM),

spacecraft adapter (SA), spacecraft adapter jettisoned (SAJ) fairings, and a launch abort system (LAS). The CM provides a habitable pressurized volume to support crew members and cargo during all phases of a given mission - from launch operations to Earth entry, descent, landing, and recovery. The SM provides services to the CM in the form of on-orbit propulsion, consumables storage, heat rejection and power generation. The LAS provides an abort capability to safely transport the CM away from the launch vehicle stack in the event of an emergency on the launch pad or during ascent.

The MPCV is being developed for crewed missions to the Moon's orbit, asteroids, and then to Mars. The capsule is also planned as a backup vehicle for missions to the International Space Station (ISS). It will be launched by the NASA developed Space Launch System (SLS).

The MPCV resembles its Apollo-era predecessors, but its technology and capability are more advanced. The spacecraft's life support, propulsion, thermal protection and avionics systems are designed to be upgradeable as new technologies become available.

The MPCV's Crew Module is larger than Apollo's and can support up to four crew members for spaceflight missions. The Service Module fuels and propels the spacecraft as well as storing oxygen and water for astronauts. The Service Module's structure is also being designed to provide locations to mount scientific experiments and cargo.

The first MPCV missions are:

- The first test flight is planned for 2014 with a Delta 4 launch vehicle that will launch the MPCV CM into a high elliptical orbit to demonstrate high speed atmospheric Earth re-entry.
- Exploration Mission-1 (EM-1) in 2017 is planned to be an un-crewed lunar flyby mission on a free return trajectory, lasting approximately one week in duration. The trajectory is designed to achieve a high speed atmospheric entry to demonstrate the MPCV entry, descent, and landing systems.
- EM-2 is planned to be a crewed lunar orbital mission, spending several days in lunar orbit and then will perform a Trans-Earth Injection (TEI) burn to begin the return to Earth.

Figure 2 shows an artist impression of the MPCV with an ESA built SM on the way to the Moon.

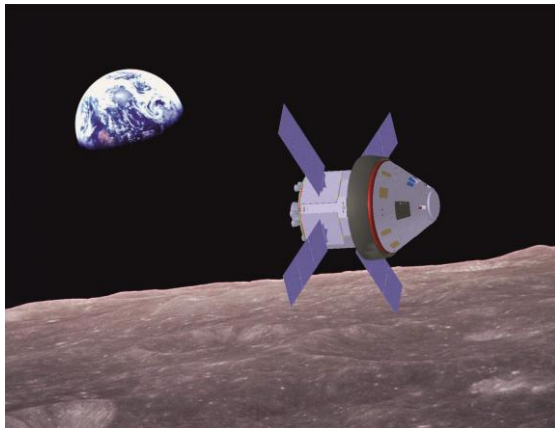


Figure 2: MPCV artist impression

Figure 3 illustrates the EM-2 mission as the first crewed MPCV flight.

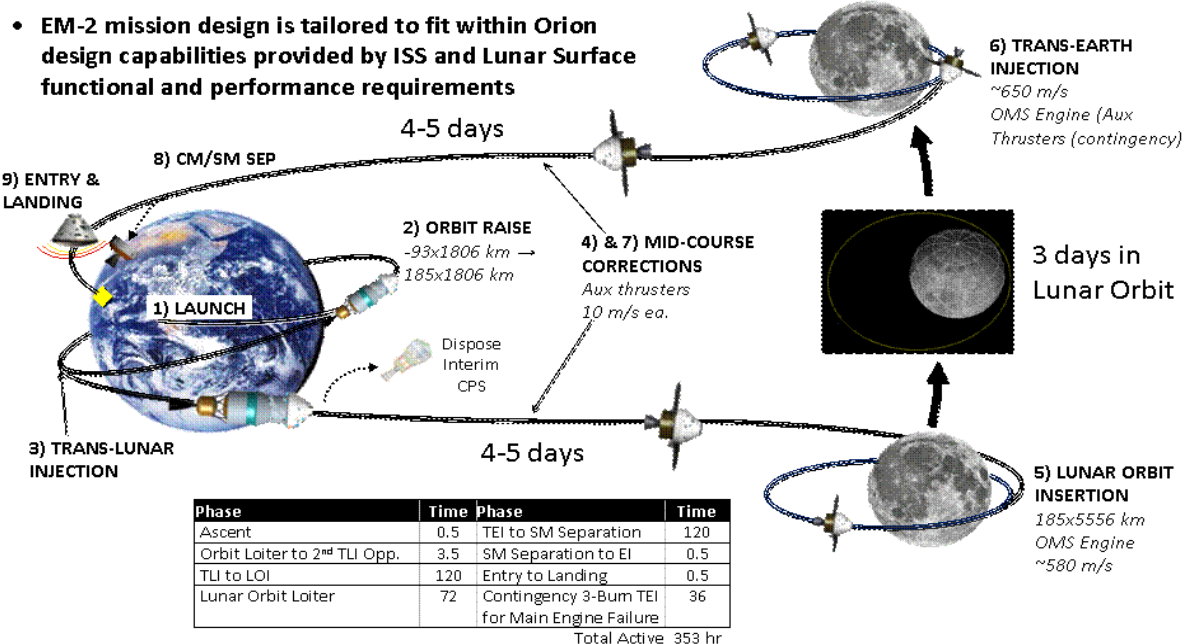


Figure 3 : MPCV Exploration Mission EM-2

III. MPCV-SM ESA CONCEPT

The Crew Module and Service Module will physically interface via an interface ring called the Crew Module Adapter (CMA). The Service Module is attached to the CMA for the duration of the mission. Just prior to the Earth entry, the CMA separates from the CM for CMA/SM disposal and the CM performs final re-entry and landing operations.

NASA is responsible for development of the CM, CMA, SAJ and LAS elements of the MPCV. The CMA provides the structural, mechanical, electrical, and fluid interface between the CM and SM. In addition, the CMA houses communication equipment, sublimators for thermal heat rejection,

and power and data control/interface electronics. NASA will also be responsible for the spacecraft adapter jettison fairings (SAJ). The SM is enclosed by three spacecraft adapter fairing panels which protect the solar arrays, radiators, and thrusters from launch and ascent loads. The fairings may be jettisoned during the ascent phase or following main engine cut-off of the launch vehicle.

ESA will be responsible for the Service Module and Spacecraft Adapter. SM functions include propulsion for ascent orbit circularization, orbital and reaction control maneuvering, trans-Earth injection, and mid-course correction maneuvers.

The SM provides life support consumables, power generation and storage, heat rejection, and volume

reserved for unpressurized cargo. The SM also provides abort to orbit capability during portions of the launch profile. For the ISS backup mission, the SM provides the capability for approach maneuvers, rendezvous, ISS departure, and return trajectory insertion.

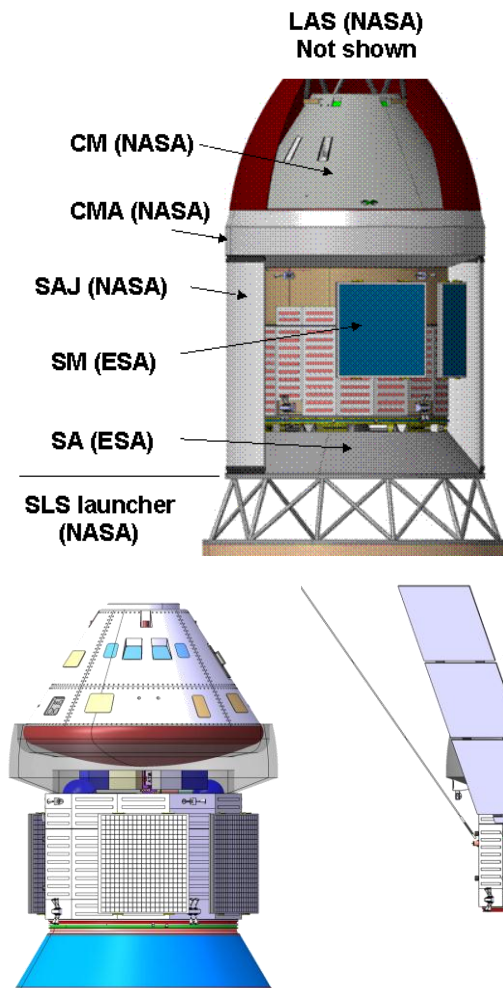


Figure 5: MPCV-SM Launch / On-Orbit Configuration

The major SM parameters for a lunar mission are:

- Dimensions : approx. 4 x 4 m
- Dry mass : approx. 3800 kg
- Fuel : approx. 9200 kg
- Solar array power : approx. 11 KW
- Heat dissipation : up to 5 KW
- Propulsion :

Figure 4 : MPCV NASA and ESA elements

For the lunar mission, the SM provides propulsive rendezvous capabilities for docking to other potential lunar mission elements; lunar orbital maneuvering propulsion for the MPCV Spacecraft; maneuvering propulsion for return to Earth trajectory insertion and course correction propulsion maneuvers during the return to Earth.

The Spacecraft Adapter (SA) provides the interface to the launch vehicle during launch. During launch and ascent, the SM and SA will be enclosed by the SAJ. The SA attaches to the aft end of the SM to the Launch Vehicle and includes the structural interface, separation mechanisms, and umbilical connectors for communication between the launch vehicle and the MPCV Spacecraft. At launch vehicle burnout, the MPCV Spacecraft separates from the SA at the SM/SA separation plane.

Figure 5 illustrates the ESA Launch and On-Orbit Configuration for the MPCV-SM. (3)

- 1 main engine, approx. 30 KN
- 8 auxiliary thrusters each 490 N
- 16 or 24 RCS thrusters each 220 N

Ariane 5 compatibility: Beside the primary MPCV-SM functionality a key aspect for ESA is the compatibility of the MPCV-SM for potential European applications and utilization of Ariane 5 as launch system.

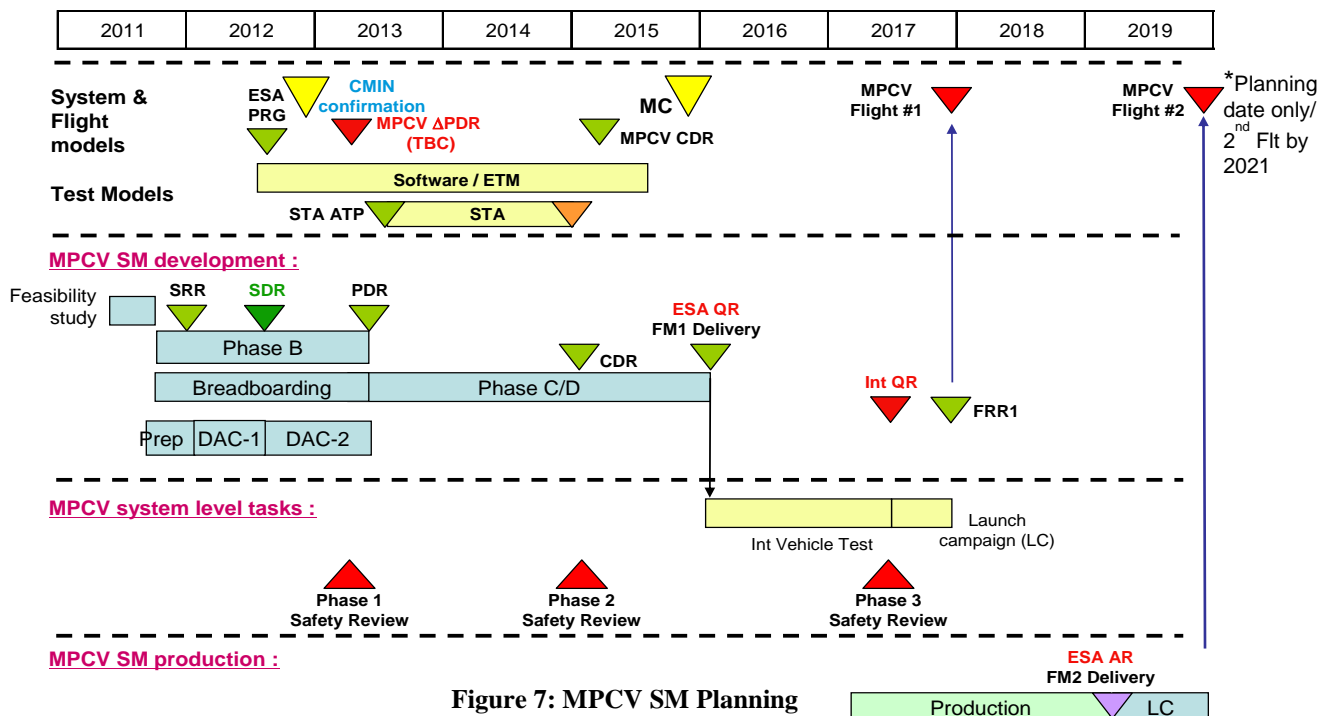
IV. PROGRAMMATICS

The major program planning assumptions utilized for the Phase A/B1 study are as follows:

- **Design approach:**

- ESA will design the SM in accordance with NASA provided requirements (functional, performance, safety, environment, ...)
- NASA will provide selected subsystems as GFE: e.g. Main Engine (STS OMS-E) & TVC

- **Schedule:**



- **Development philosophy :**

- System Requirements Review (SRR) was performed in Phase A
- SDR (System Definition Review) at end of phase B1
- Phase B2 to be completed with PDR
- Bread-boarding of critical subsystems in phase B1/B2 (goal TRL 5)
- Safety reviews :
 - Phase 0 prior to MPCV-SM SDR

- EM-1 mission at the end of 2017
- EM-2 mission in 2021, however NASA is aggressively pursuing options which pull forward the second flight

- **Reproducibility:**

- NASA and ESA will work closely together throughout the design and development to ensure independent reproducibility of the ESA designed SM at the conclusion of the Implementing Arrangement. ESA and its contractors may procure some of the SM hardware from US sources.

- Phase 1 at MPCV-SM PDR
- Phase 2 at MPCV-SM CDR
- Phase 3 at MPCV-SM PFM QR

For planning purposes, NASA and ESA have agreed to the following planning assumptions for the MPCV-SM development:

- **MPCV SM :**
 - SRR January 2012
 - SDR September 2012
 - PDR Mid 2013

- CDR Dec 2014
- QR Dec 2015
- MPCV Vehicle CDR: February 2015
- SM STA delivery (TBR): Dec 2014
- Flight 1 SM delivery: February 2016
- Flight 2 SM delivery (TBR): Dec 2018

Figure 7 illustrates the MPCV program planning.

V. PROJECT STATUS

Project phases 0/A have been performed between May 2011 and January 2012 concluding with a System Requirements Review. Phase B1 has been kicked-off early February running until November 2012 in order to prepare the technical and programmatic baseline for ESA - NASA decision about the implementation of MPCV-SM as a post ATV-5 barter.

Phase B1 will include an integrated NASA - ESA (supported by industry) Design Analysis Cycle - 1 (DAC-1) and a joint System Definition Review SDR in September 2012.

NASA is supported by Lockheed-Martin and its team on the US side. In Europe Astrium ST in Bremen (as prime) and Les Mureaux with TAS-I Turin as a main partner plus other European suppliers from Germany, Italy, France, Belgium,

Switzerland, the Netherlands, Spain and Austria are supporting ESA in phase B1.

VI. PERSPECTIVE USE IN GLOBAL EXPLORATION ROADMAP

The Global Exploration Strategy: the Framework for Coordination, released in May 2007 by 14 space agencies, presents a vision for globally coordinated human and robotic space exploration focused on solar system destinations where humans may someday live and work. It calls for sustainable human exploration of the Moon, near-Earth asteroids, and Mars. Although Mars is unquestionably the most intriguing destination for human missions currently within our grasp, and a human mission to Mars has been the driving long-term goal for the development of the Global Exploration Roadmap, there is much work to be done before the risks associated with such missions can be reduced to an acceptable level and the required technologies are matured to enable a sustainable approach.

VII. ACKNOWLEDGEMENTS

The work performed was initiated and guided by the NASA - ESA ISS / MPCV program management, namely Mike Suffredini and Mark Geyer from NASA and Bernardo Patti from ESA.

Mission Scenario: Moon Next

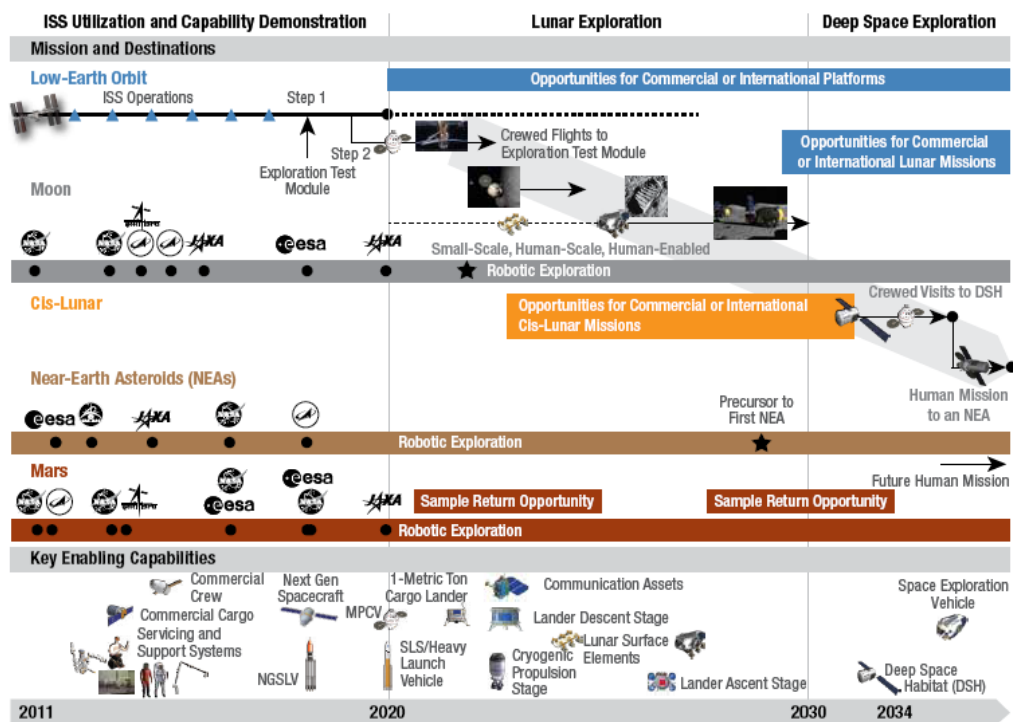


Figure 8 : Global Exploration Strategy Moon Next Scenario

VIII. CONCLUSIONS

The inclusion of an International Partner in the development of the MPCV can be of benefit to both NASA and ESA and provides an opportunity for a significant International contribution towards NASA's exploration program. An ESA provided SM could accelerate the first crewed Orion MPCV flight by freeing the US contractors to concentrate on the Crew Module and Launch Abort System. An international partnership is consistent with the US National Space Policy to promote appropriate cost and risk sharing among participating nations through International partnerships. If the Implementing Arrangement is approved by both Agencies, it does not entail a long term commitment yet is an opportunity to build on existing strong cooperative relationships between NASA and ESA.

In addition, the MPCV SM provides ESA an opportunity for cooperation that builds on existing ATV Service Module technology, leveraging skills and knowledge created for ATV. An MPCV SM would also benefit ESA in the development of additional capability for use toward future ESA missions, creation of long term cooperation on

future programs and will strengthen the strategic partnership with NASA.

The NASA and ESA teams including their respective contractors have worked very well together and have made swift progress towards the advancement of both a technical and programmatic baseline for an ESA provided SM.

IX. REFERENCES

- [1] *Agreement among the Government of Canada, Governments of Member States of the European Space Agency, the Government of Japan, the Government of the Russian Federation and the Government of the United States of America Concerning Cooperation on the Civil International Space Station* (referred to as the ISS IGA), signed on January 29, 1998
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